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ABSTRACT

An overview of the Lincoln Training System (LTS) and descriptions of the hardward and software of the LTS-1 and LTS-2 systems are provided. The overall program seeks to develop, test, and evaluate technical aids to vocational training systems. These are appropriate to this field because the high costs need to be reduced and because there are clear objectives which can serve as criteria of success. The LTS uses microform techniques for information storage, and response branching logic. Broad specifications for LTS are: 1) random access from frame to frame in less than one second; 2) the capability to handle graphic material, including text, diagrams, and halftone reproductions; 3) a display of 30-60 seconds of voice quality audio per frame; 4) response selection logic which is stored photographically with each frame; 5) console keyboard with provision for author-regulated responding and student browsing; and 6) an option to use a computer for course management and student monitoring. LTS-1 is a mock-up system using commercially available components, designed as a preliminary evaluation of the system specifications given above. LTS-2 is a prototype microfiche system undertaken for design and component development purposes. (LB)

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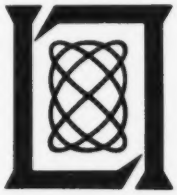

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A program in Educational Technology was initiated by the Laboratory in November 1969. It was first reported in the 15 February 1970 General Research Quarterly Technical Summary. Background material from that report is included here so that the present series of reports will be complete and self-contained.

F. C. Frick
Program Manager

15 June 1970

Accepted for the Air Force
Franklin C. Hudson
Chief, Lincoln Laboratory Office

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EDUCATIONAL TECHNOLOGY PROGRAM

I. INTRODUCTION

A number of Laboratory studies conducted over the past several years have suggested the feasibility of developing technical aids that would significantly increase the productivity of our present educational and training systems. Specifically, this would involve a machine such as a computer to support individualized and self-paced instruction. Such a system would operate, in effect, like a private tutor.

To date, most of the development work in this area has been directed either at very simple teaching systems constrained by restricted capabilities or at very large computerized systems constrained by economics. All systems are hampered by the problems of lesson development. Relatively little effort has gone into the direct support of technical or vocational training, although it would appear that these areas of "special" education set the most urgent requirements for technical support and offer the greatest opportunity for successful development.

In the first place, these are areas where the cost per student hour is very high. In contrast to the $.50 to $.75 for primary schooling, technical training in the Air Force runs $5 to $6 per student hour for large input courses and considerably higher for more specialized training. In the second place, there are agreed upon objectives and standards. There is no implication of schooling as "baby sitting." Technical innovation can be objectively evaluated and translated directly into savings of manpower and dollars.

A system that can effectively support technical/vocational training must, however, meet certain rather stringent requirements:

(a) It must handle complex graphics, including halftone and color.

(b) It should include an audio capability to compensate for capable students with low to average language skills.

(c) It must support a substantial degree of interaction. We cannot expect students to be highly motivated; interaction is necessary to maintain interest and attention, to guide the student and, in particular, to provide knowledge of progress.

We believe that these general requirements can be met, and the Educational Technology Program is directed at the development, test, and evaluation of such a system. As currently envisioned, we plan to employ photographic (microform) techniques for the storage of all lesson specific information, picture, sound, and response branching logic. Through this means, much of the flexibility and interactive support of a conventional CAI system can be achieved without the requirement for a large computer, a wideband communication system, or a large external storage bank.

II. PROGRAM

Based on the general considerations outlined above, we have arrived at the following broad specifications for the Lincoln Training System (LTS):

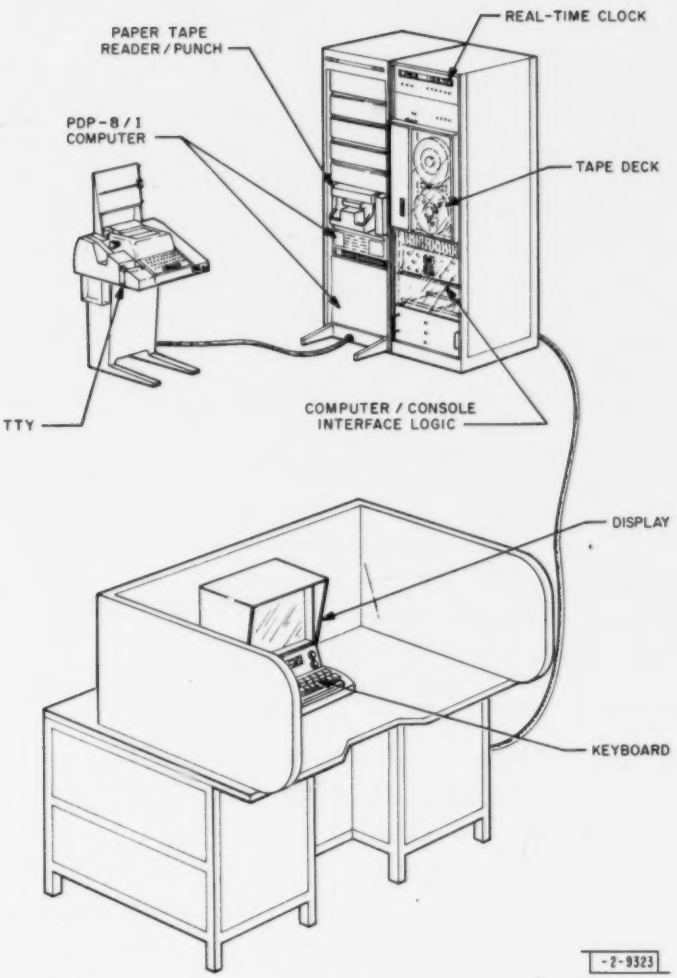

Fig. 1. Block diagram of LTS-1.

(a) Random access from frame-to-frame of audio/visual material in less than one second.

(b) Visual material to include text, diagrams, and halftone reproductions.

(c) A display of 30 to 60 seconds of voice-quality audio per frame.

(d) Response selection logic to be stored photographically with each frame.

(e) Console keyboard with provision for author-regulated responding and for student-initiated browsing.

(f) An option to use a self-contained computer for course management and student monitoring.

A general requirement exists for the development of an associated "author's facility" to support the production and editing of course material, and the adaptation of existing material to meet special requirements of the LTS.

In order to evaluate these design features and system parameters, a mock-up system, LTS-1, has been constructed using commercially available components. Functionally, this version looks to the student and the author much like the ultimate system. Concurrently, design studies and component development are being undertaken for the first microfiche system, LTS-2.

III. LTS-1

A. System Hardware

A student terminal was designed and constructed during the past six months and has been in operation since mid-May. This system has provision for handling up to 200 frames of audio/visual material with average access time of 1 second and maximum access time of 3 seconds. Each frame consists of a 35-mm film transparency and a magnetic disk for storing up to 60 seconds of audio material. LTS-1 will be used to evaluate educational material, LTS-2 design concepts and system parameters such as number of frames required, maximum access time frame-to-frame, and amount of audio required per frame. A pictorial view of the system is shown in Fig. 1, in which each of the principal components is identified. Although minor hardware debugging continues, the terminal is being used as an author facility for assembling and testing programmed instructional material.

The principal components of this system are four Minnesota Mining and Manufacturing Company (3M) "Sound-on-Slide" 35-mm projectors under control of a PDP-8/I computer. The projectors have been modified to handle 50 slides per tray, thus affording a 200-frame capability. The images are selected by mirrors and projected onto a "page size" screen ($8\frac{1}{2} \times 11$ inches). A schematic view of the four projectors and mirror optics is shown in Fig. 2. A system control keyboard and loudspeaker are also part of the console. The audio content per frame is 60 seconds and can be segmented by the course author, using recorded cue signals which interrupt the playback. The student may continue the playback or he may repeat the entire audio frame. All program branching is under direct control of the computer.

1. LTS-1 Console

The console shown in Fig. 1 was designed to hold the four 3M projectors, mirror optics, electronic servos, and power supplies. The surface of the unit is standard desk size with a

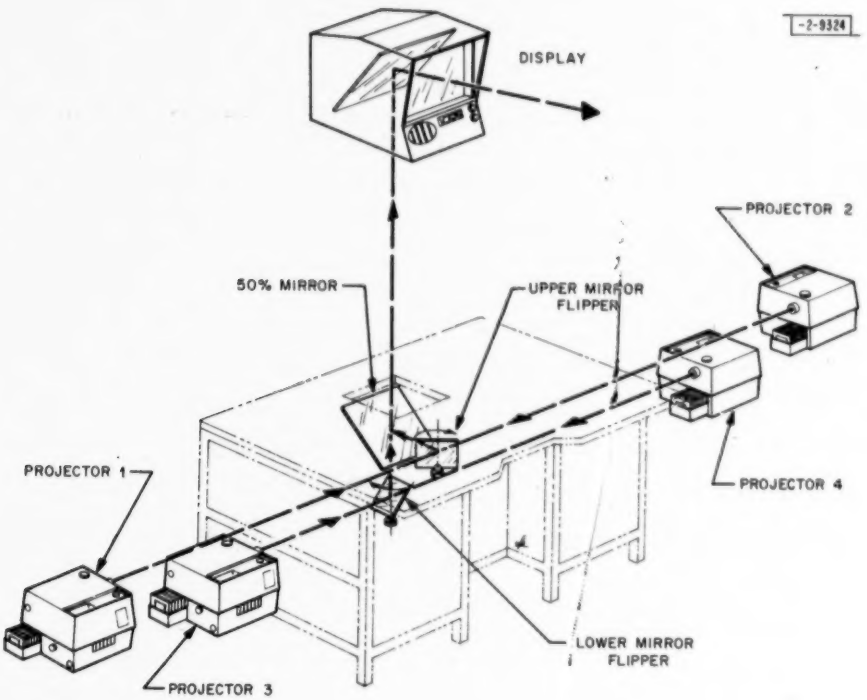

Fig. 2. LTS-1 (optics).

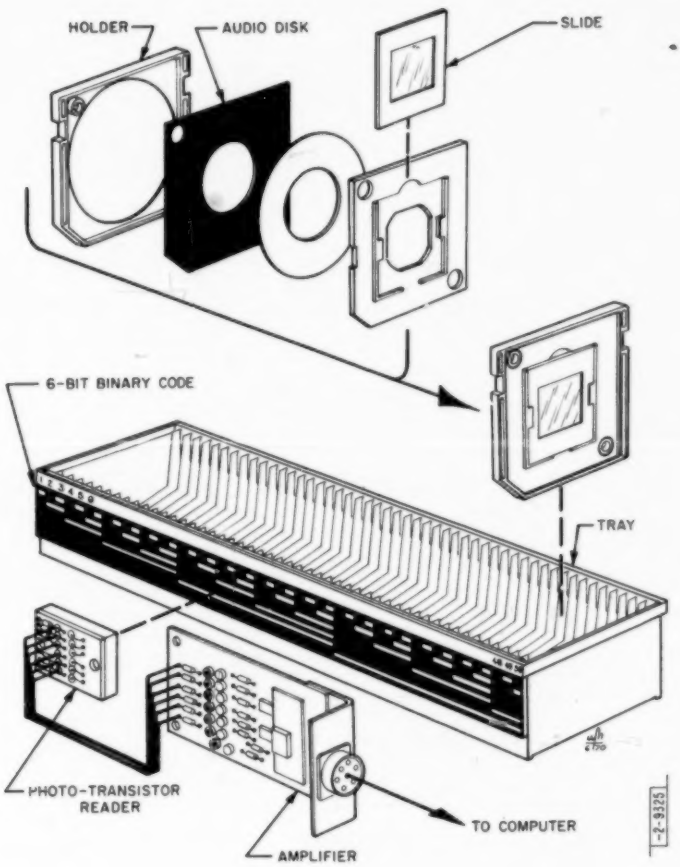

Fig. 3. Slide holder and tray.

carrel lined with acoustic tile surrounding the work area to provide privacy and reduce noise interference. The console framework is constructed of extruded aluminum members which are heavy enough to provide rigid support for the projectors and mirror system and to assure a stable visual image on the projection screen. On top of the work surface is the display housing. It supports the final mirror and has been made large enough to accommodate screen sizes up to 12 × 15 inches. The present screen is an $8\frac{1}{2}$- × 11-inch PolaCoat "Lenscreen" material. At the base of the unit are the audio and focus controls and a loudspeaker.

The 3M projectors and slide trays were extensively modified for use in this system. The slide trays were extended to hold 50 slides. A pictorial view showing details of the slide holders, trays, and electro-optical tray position reader is shown in Fig. 3. The manufacturer's slide tray advance mechanism was replaced by a DC drive system to permit control by the PDP-8/I computer. Additional interlocking features were added to provide fail-safe protection to the internal slide-lifting mechanism. A block diagram of this control system is shown in Fig. 4.

The projectors have been positioned in the console to achieve identical optical path lengths to the screen (approximately 60 inches). Two mirror drive systems respond to computer commands to select one of the four projectors for display. The projection lamps are interlocked to the mirror selection system, allowing only one projector to display at one time.

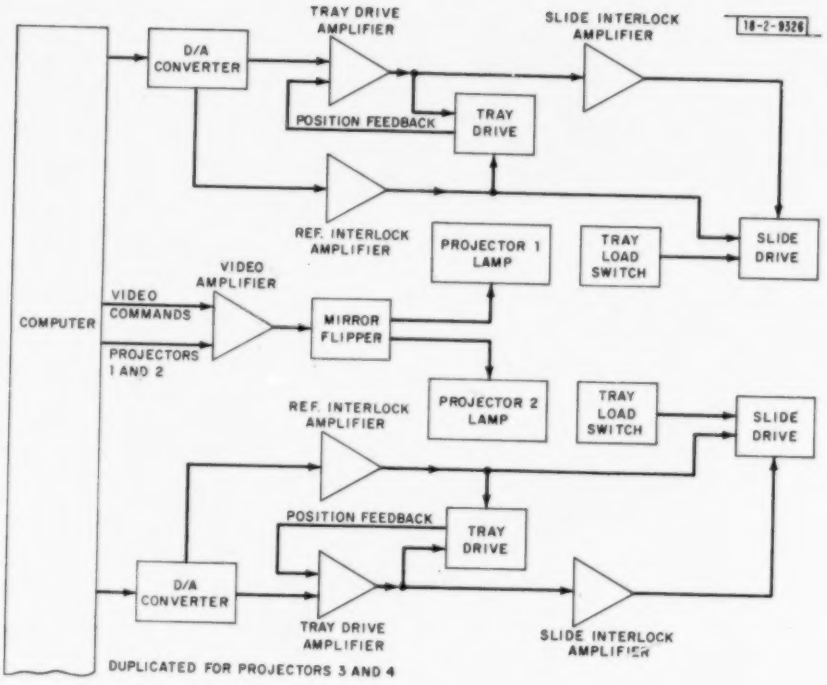

Fig. 4. Block diagram of frame positioning and projection subsystem.

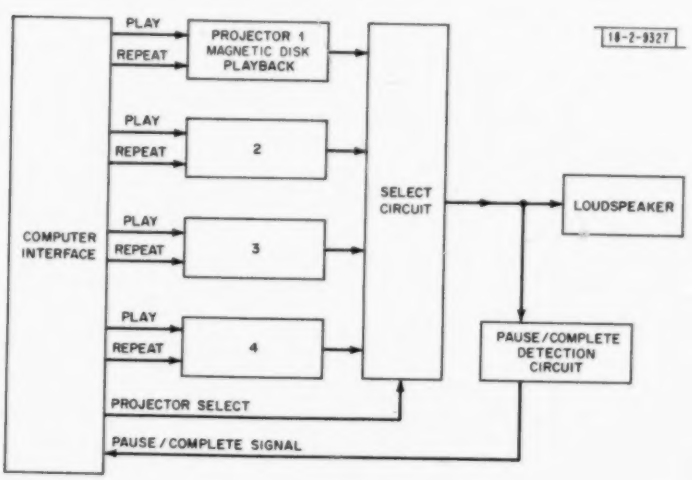

Fig. 5. Block diagram of audio subsystem.

A reflective strip that provides 6 bits of position code is attached to each slide tray. It is monitored by a photo-diode array which provides the tray position in digital form for computer access. The status of the projection lamp (video status) is monitored for input to the computer by the use of a photo-transistor. This signal also enables the focus control circuit, allowing only the projector which is active to be focused.

2. Audio Subsystem

A sound track is associated with each picture. The 60-second track is segmented with PAUSE cue signals and finished with a COMPLETE. During record, the PAUSE and COMPLETE cues are placed on the disk by the author. During playback, the start of the next section of audio following a PAUSE, or the change to a new frame following a COMPLETE, is controlled by student response.

The basic 3M audio record/playback mechanism consists of an annular magnetic disk, as shown in Fig. 3, scanned by a revolving magnetic head. Grooves in the disk guide the head on a 60-second spiral path from the outer to the inner edge.

Each projector in the console was modified in two ways: (a) to provide digital control of the drive (start-stop) and of the frame repeat (electromechanical resetting of the head to the beginning of the track), and (b) to provide PAUSE and COMPLETE cue tone detection from a digitally selected projector. A block diagram of the audio subsystem is shown in Fig. 5.

3. Computer and Control System

The control philosophy of LTS-1 contrasts with that planned for LTS-2 in that only trivial control loops are closed within the console itself. In this test environment, it was felt that the machine should be under control of the computer program to a maximum extent in order to make it easier to monitor machine performance and to make adjustments of operational doctrine. Thus, not only the branching logic, written by the author and keyed to student responses, but also the sequence of events in the frame cycle are controlled by the computer.

All these functions are performed with a small fraction of the computer capacity available. Of the 4000 12-bit words of core, 1000 are devoted to control and monitoring programs and 2000 to the branching logic table. Currently, the data transfer between computer and console is at a very modest rate.

Our initial experience on LTS-1 confirms our expectations for LTS-2. Eventually, the logic table will be on the fiche and control functions will be contained in the console. Except for monitoring the student and the machine, there will be no need for central computer assistance to instruction.

LTS-1 is operated under the control of a Digital Equipment Corporation PDP-8/I computer, which is a small-scale, general-purpose, digital machine with a 4000-word, random-access, magnetic core memory and 1.6 microseconds cycle time. A useful feature is its ability to execute an instruction skip and program interrupt as a function of external input/output (I/O) device condition. System peripheral equipment includes the standard teletype, a high-speed perforated tape reader, an incremental magnetic-tape recorder, and a 24-bit digital clock.

The various computer interface I/O functions are performed through new IOT instructions implemented in the interface hardware (see Fig. 6). This is accomplished by creating a number of "devices" hung on a single bus, each with its unique 6-bit address code. When a device

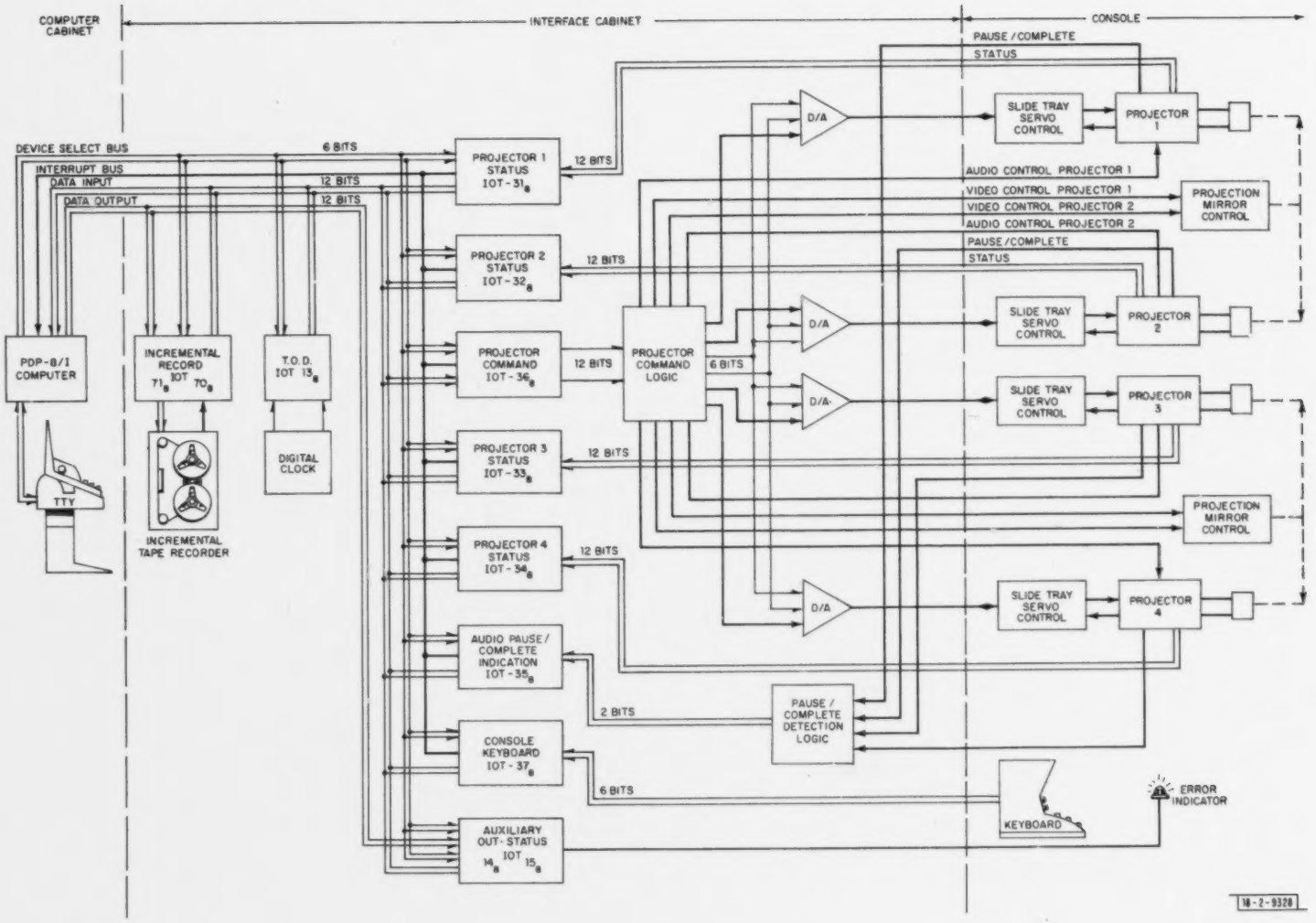

Fig. 6. Block diagram of control system.

recognizes its code, it takes action. If the IOT is a computer command, the accumulator is read and decoded into an operation, e.g., "turn on the lamp." If it is an input, bits are loaded into the accumulator to be used later by the program.

Some notion of the level of control can be obtained from a brief review of the IOT's. The basic IOT command causes a slide to move into position, enables audio or restarts audio, and turns on the lamp. In fact, this command must be given twice – once to move the slide tray, and later to turn on sound and picture. The turning on occurs after the status has been checked with another kind of IOT, one for each projector number. Status, as distinct from command, is a report of how things really are. Is the lamp on, as measured by a photocell? Is the audio relay closed? What locations do the photocells read for slide position of the tray? A separate IOT can be issued to say whether the audio has encountered a PAUSE or COMPLETE. This signal is used, for example, by the program to interpret a GO ON response. That is, GO ON plus PAUSE means "play more audio," but GO ON plus COMPLETE leads to a new frame if the lesson logic permits.

Other IOT instructions are used to read the 6 bits of response code from the student at the keyboard, to read the clock, to read status, and to record events on the incremental, magnetic-tape, data recorder. Another pair of IOT's is devoted to a 12-bit external register. One IOT commands a word into the register and another reads it out. One bit, by way of example, turns on the red error light on the keyboard panel. The remainder are reserved as a means of communication with auxiliary instructional devices, such as a special training device, tape recorder, motion picture projector, etc.

4. Author Facilities

The problem of producing course materials for LTS-2 divides itself rather naturally into two phases: course preparation and final fiche production. We have satisfied ourselves that the art of producing fiche is currently adequate to meet the most rigorous LTS demand, namely, the reproduction of audio information. In contrast, facilities to support authors in the generation of course material have not been systematically investigated, and the development of improved author facilities is an important part of the present program.

The usual experience in the development of lesson material in a branching instruction environment is some 100 hours of preparation time for each hour of student time. In the LTS environment, the demands are exacerbated by the addition of an audio dimension. The problem is one of producing picture, audio, and branching logic for each frame and bringing them together in an acceptable form for review and for testing and evaluation with students. Numerous revisions of each lesson can be expected, and any technical aid that will simplify and speed up the editing and revision process will have an important effect.

So far, the only part of the system that has received major attention is the production of audio for LTS-1. The manufacturer's system proved awkward and inadequate for large-scale recording and re-recording of sound slides. A console for this purpose has been designed, constructed, and placed in operation.

The facility, located in an acoustically insulated room, includes:

(a) A 3M Model 123/525 Projector Recorder, modified to improve the author-machine interface, to allow PAUSE/COMPLETE cueing, and to extend recording time to 60 seconds.

(b) A presentation of frame visual information, similar to that observed by the student on the console.

(c) Provisions for microphone and tape sources and for external record and playback processing, such as speech clipping and bandwidth truncation.

(d) Provisions for generation and playback of PAUSE/COMPLETE cues.

In order to relieve authors of all unnecessary operations, functions were combined into a few simple control buttons and switches. A 15-minute lesson has been prepared and runs as a linear teaching program on the audio console itself.

The audio console has proved to be easy to learn and to use. The spoken part of each frame is written out in advance. Recording each frame takes little more time than required to speak it and to play it back as a check. An AVC circuit to help the novice maintain a constant voice level is perhaps the only feature lacking in the current facility.

For the most part, graphical material has been produced using typewritten materials and drafted illustrations. One lesson, consisting largely of text, was produced on the Lincoln Editor facility, on-line to the IBM 360/67 computer. As it stands, this appears to be a very useful way to get printed text of adequate quality for test purposes. The main advantage is that revision is a much easier process on-line to a computer. The lesson logic for LTS-1 is generated using the Editor and Assembler provided with the DEC PDP-8 machine. It is a somewhat cumbersome but routine clerical procedure.

5. Auxiliary Equipment

The audio record/playback mechanism of the 3M "Sound-on-Slide" projector has been incorporated into a special-purpose audio "transient memory" device for use in a language training environment. Dr. B. A. Green of the M.I.T. Education Research Center first pointed out to us the need for devices of this type. In a typical situation, a student listens to an author tape and repeats certain material orally, sometimes into a second tape system for playback. The rewind delays and the need to locate the beginning of the previously recorded track on the tape reel are technically undesirable. A simple tape loop forces a trade-off between recording time and delay to playback time.

A more desirable system would provide the following features:

(a) An author transient memory into which selected portions of the master tape could be transferred as they appear in the lesson and conveniently replayed with less than 1-second rewind delay. After each transfer, the master system would automatically turn off until the student had mastered the dumped portion and had decided to proceed further

(b) A student transient memory to allow the student to record and play back responses while simultaneously listening to the author transient memory.

(c) Both transient memories would have 30 seconds capacity and would rewind in less than 1 second, independent of record length.

A typical learning session might then occur as shown in Fig. 7.

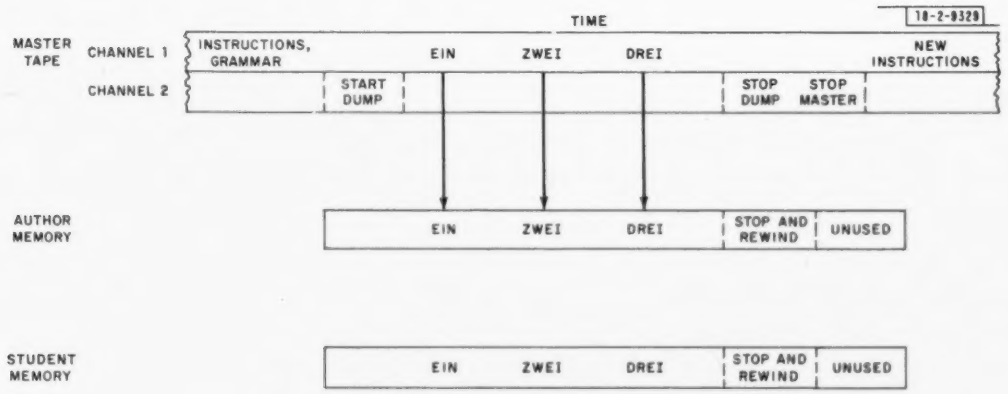

Fig. 7. Language application of transient memory system.

A prototype student "transient memory" was constructed and tested during May 1970 and demonstrated that the device was suitable for the purpose intended. Work will continue in this area to obtain higher record/playback fidelity and to construct a full system including an author transient memory.

B. System Software

The purpose of LTS-1 is to provide a realistic test facility to study the display and control features of this kind of learning machine. To the student, the console provides displays and a keyboard to support interaction (Fig. 8). To function, the machine requires two forms of "software": (1) a program to interpret responses, to control picture and sound, and to record data, and (2) lesson material, including 35-mm slides, sound records, and the branching logic table unique to each lesson.

A brief description of student operation is required to understand the general requirements. There are two modes of student operation: regulated and browsing. In regulated mode the student follows the lead of the author. He reads material and listens to the audio. Then he proceeds by selecting a response; e.g., a YES or NO to a question, a letter as a multiple choice response, or a simple GO ON if no choice is offered. These responses are provided for in the

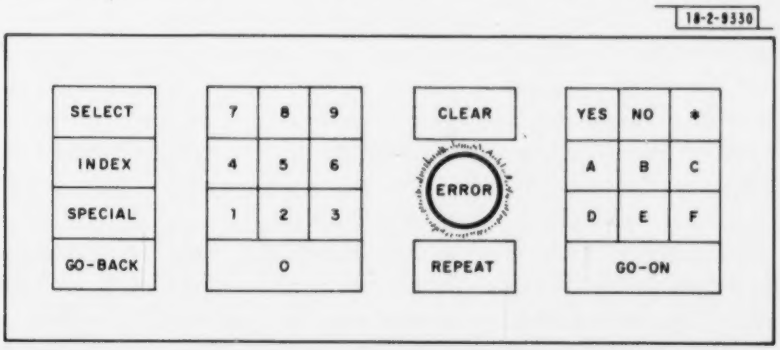

Fig. 8. Keyboard.

right-hand panel of the keyboard. The student is also free to browse, to find selected material, skip forward or back, etc. He first looks up a guide to the lesson by pressing INDEX. Then he may enter at any point in the lesson by inserting the entry number and pressing SELECT. These are the principal response features used by the author in the development of a lesson.

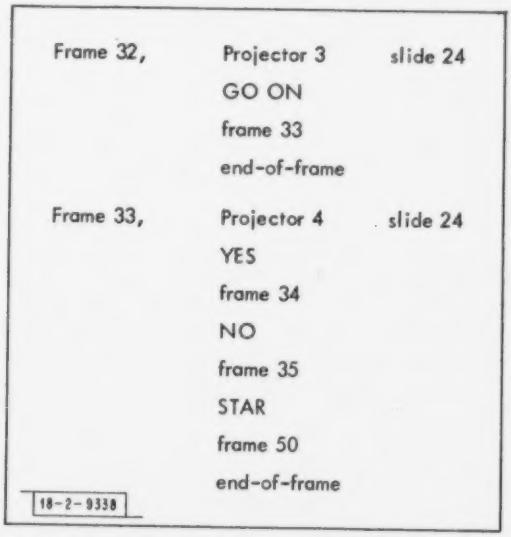

Fig. 9. Example of two frames from a lesson logic table. A linear frame, followed by one with a three-way branch, STAR (*), might be for a "not sure" response. Other responses would produce a keyboard error signal.

The author prepares a lesson logic table for use by computer (see Sec. III-A-4). All the information unique to a lesson relevant to both regulated and browsing modes of student action is contained in this table. A typical piece of table is given in Fig. 9. Not shown is the "block table," a list of entry points keyed to the INDEX frame, also written by the author.

1. Educational Technology Operating System (ETOS)

ETOS-1 is a set of computer programs which controls the presentation of the lesson and records performance data for LTS-1. This system monitors each event at the instructional terminal. Using the course author's lesson logic table as a script, it moves through a lesson on cue from the student and from the apparatus. It displays slides, plays sound, records events, detects errors, interprets responses, and moves on to new frames.

The system saves all events on magnetic tape for later analysis. An event is any action at the console such as a keypush, a signal that a slide is positioned, etc. The computer is so fast that the system will in fact be idle for most of the time during a lesson. Therefore, provision is made to run other computer jobs while waiting for action from the terminal. These are called background jobs because they are executed only in the absence of other work and are shelved the instant that a signal arrives from the terminal.

Despite the great speed of the computer, there is no guarantee that each event will be completely handled before another occurs. A new event may occur, for instance, while the system is consulting the lesson logic tables, or while saving the last event. Therefore, the system is organized to perform its work asynchronously from incoming event signals, and its activities are divided into four levels of priority:

1.	Stack events in buffer	Immediate
2.	Process events	As fast as possible
3.	Record events	After all processing is caught up
4.	Background	After all events are taken care of

These four levels of activity are handled by four distinct classes of routines. The routines in each class call one another either until (a) they are interrupted and go to a lower numbered level, or (b) there is no more work for them to do and they go to a higher numbered level. For example, the routines that perform event processing (level 2) may chain control from one to another for a while with time out for level 1 but no time for 3 or 4, until done. At any time, regardless of what the computer is actually doing, the following four streams of activity may be considered to be in process:

1. Buffer chain
2. Processing chain
3. Save chain
4. Background chain

In many ways, the processing chain is the brains of the LTS-1 console. It is prepared to handle any contingency, legal or otherwise, set up by the operation of the apparatus and responding of the student.

The monitor is a routine that directs the attention of the computer to one or another of the chains. The monitor is event-driven in the following sense. Each event is made known to the computer through an interrupt. Whenever an interrupt occurs, any computing in progress is suspended and control is given to the monitor, which invokes the buffer chain. When the buffer routines have completed their work, the monitor gives control to the processing chain. When the processing routines have caught up on all processing, the monitor passes control to the save chain. When the save routines have recorded every event, the monitor passes control to any user-supplied background routines, which make up the background chain. The background routines remain in control until a new interrupt occurs. Interrupts are disabled (ignored) in the buffer chain and in the monitor; all other routines can be interrupted. Thus, at any stage of the above progression, control can be sent on interrupt back to the buffer chain, and the whole progression from chain to chain is started anew.

The present system, ETOS-1, permits expansion by the simple addition of more routines. This can be done without regard for timing because the rate of human and equipment events is always very low. The initial system is straightforward in several respects. (a) Since there is only one terminal, the buffer chain does nothing but incrementally fill a single storage area. (b) The processing chain mainly reacts to individual button pushes, one at a time. There is no elaborate interpretation of responses. (c) There is no real-time analysis of data. Information is shipped directly to the incremental recorder.

As the system becomes more elaborate, the buffer chain may be enlarged to distribute events from different consoles into different buffer areas, the processing chain may be enhanced to encompass parsing activities, and the save chain may be modified to engage in printing or higher-speed storage activity.

2. Course Material

During the reporting period, a variety of demonstration and instructional materials have been developed for use with the LTS-1 terminal.

A 100-slide unit on the principles of amplitude modulation (AM) and single-sideband (SSB) has been developed and programmed for use in the terminal. The material has been taken in part from a programmed instruction package in use at Keesler Technical Training Center. The Keesler package is a linear "workbook" lesson. Our adaptation is part linear and part branching with multiple choice responses. Figure 10 is a flow chart of one of the branching portions of the unit. This particular portion requests three responses from the student; branches are then dependent on response. Each block represents a separate frame – picture plus audio. Blocks with the same numbers, however, contain identical visual material. Primes and double primes are used to indicate that the audio associated with that particular slide is different from the audio associated with the slide with no prime. This section is, in fact, a brief test of the student's knowledge, with appropriate remarks and actions after each response.

In this unit on AM and SSB good use has been made of the audio. It has been possible to demonstrate directly the effects of overmodulation on speech intelligibility and to illustrate speech quality degradation which results from mistuning the receiver reference frequency in a

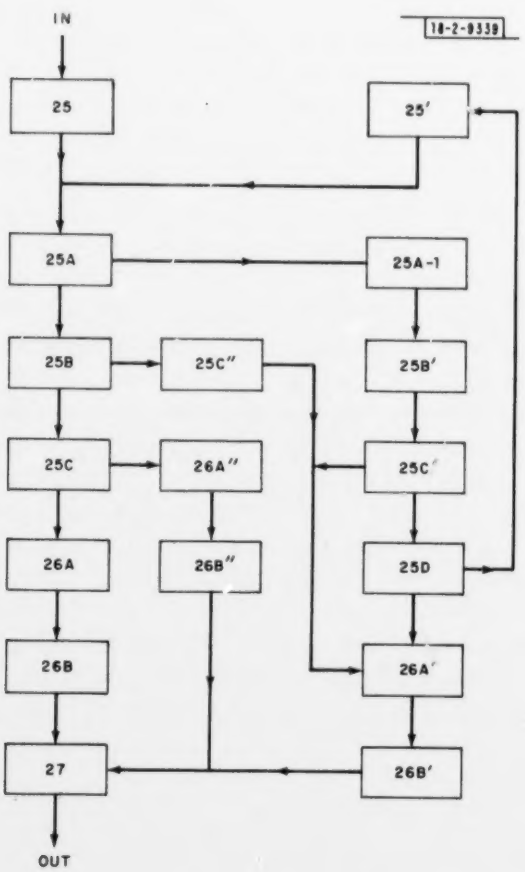

Fig. 10. Flow chart of lesson block.

SSB system. The objective in preparing this unit was, of course, to obtain experience with the vocational/technical subject matter with which we expect to be working in the future.

Self-instructional units have been assembled which teach the student how to use the hardware that has been constructed. One unit of 40 slides introduces the student to use of the LTS-1. The student is requested through visual and audio channels to operate the various commands available to him at the console. The program responds appropriately to student action. The availability of this unit insures that each student will have the basic knowledge required to operate the console in the conventional lesson and relieves the individual authors of this task. As mentioned above, a linear set of about 25 slides has been assembled which teach an author how to use the audio recording console.

It has been noted that some of the material programmed is adapted from existing Air Force Training documents. It is our intent to use existing material to the fullest extent possible, modifying as required to take advantage of the interactive and enrichment capability of LTS-1. For example, a unit on weather has a slide sequence taken from an Air Force training film, illustrating the buildup of thunderheads at a warm front. These have been placed in the machine so that they may be played in sequence. While the sequencing is too slow to give any direct sense of motion, it is fast enough so that the progression of events is very clear.

In this same general vein, we have given considerable thought to the problem of media selection and the need, in particular, for motion pictures and video tape. It is our opinion that, in many cases, slides or (eventually) microfiche are as good as motion pictures and, of course, they are much less expensive. As a demonstration of this general philosophy, a half-hour video tape on modulation was obtained from Keesler and converted to a synchronized slide show. A slide was made of each unique frame on the video tape, and the entire sound track was stripped onto an audio tape. In the half-hour video tape there were about 100 unique frames. The converted lecture has, in our opinion, lost nothing in content or interest from the original video tape.

IV. LTS-2 DESIGN CONSIDERATIONS

A. Concept

Our efforts are now shifting to the investigation of techniques necessary for designing a prototype microfiche system with all the essential features of the LTS-1 system. We are still in the concept stage but have established a set of guidelines for development:

(1) Approximately 250 audio/visual frames to be contained on two 105-mm × 148-mm microfiche which are butt-spliced to form a course card. Each frame will be 7.5 mm × 7.5 mm.

(2) Tentatively, this film will be inserted into a rectangular glass platen, which will be open-loop positioned under the audio/visual optical systems to any of the frames within 0.1 mm accuracy. This is the combined tolerance of the film dimensional change (0.1 percent) and the precision of the two-axis table. Access time between frames will be less than 1 second.

(3) Separate optics will be used for projection of the visual images and for read-out of the stored audio signals.

(4) Visual frames will be magnified by 30:1 to fill a 159-mm × 213-mm rear-projection screen and may be either black and white or color transparencies.

(5) Approximately 30 seconds of audio material per visual frame, stored on high-resolution material, using identical format as visual frames, 105-mm × 148-mm form, butt-spliced to the visual microfiche to form a complete course card.

(6) Program branching logic to be stored in visual-frame margins using 0.9 mm × 7.1 mm on each side of the visual image.

(7) Self-contained processor for programming the unit, using the stored branching logic, and student keyboard responses.

B. Design Details

The most significant technical problem associated with the LTS-2 design is the realization of a read-only memory system containing approximately 10^6 bits per frame, or an effective density of 2.5×10^6 bits/cm^2, for storage and recovery of the audio data. We are investigating techniques that will permit relatively simple acquisition, registration, and recovery in a reliable field terminal. We are trying to avoid processes which require careful material handling so that the course-fiche can be handled without concern for dust accumulation and scratches on the micro-image card.

We are also investigating techniques for preprocessing the raw audio material in order to reduce the bit-storage requirement without affecting quality or intelligibility. The complexity or cost of these techniques is not an important factor, since they may reduce the complexity of the individual terminals.

The principal recording technique now under investigation involves the use of two-dimensional diffraction patterns through which we pass collimated coherent light to form arrays of independent diverging beams. The intensity of each beam will be a function of the magnitude of the sampled audio signal. A lens system will transform angle of incidence into rectilinear offset in the focal plane. We propose to scan the audio frame with a 150-micron × 150-micron aperture to yield a 15 × 15 array of beams which will be focused onto a solid state array of sensors and processed to recover the audio samples. Thus, although a single sample occupies 100 microns^2 on the film or grating, it is spread over 15^2 times this area, reducing its sensitivity to dust or scratches. We have produced our first masks using a precision computer-driven photographic processor, and have just begun to evaluate some of the important features and problems associated with this technique, originally proposed by Dr. R. M. Lerner, Group 65. We have since learned of similar work at Kodak using one-dimensional recordings of this type.*

We are simultaneously producing computer output microfilm of sampled audio data to evaluate a more direct recovery of area-modulated signals from fine-grain, high-gamma film. In this case, acquisition and registration is much more difficult, but we will try to develop search and acquire electro-optical devices to cope with initial errors of plus or minus 100 microns.

Our efforts at this time are devoted to component research, involving linear optical beam-deflection systems, angle-to-position transform lenses, photo-diode arrays, and optical sensing and servo devices.

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*R. L. Lamberts and G. C. Higgins, "Digital Data Recording on Film Using Super Posed Grating Patterns," Photographic Science and Engineering, Vol. 10, No. 4 (July-August 1966).

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